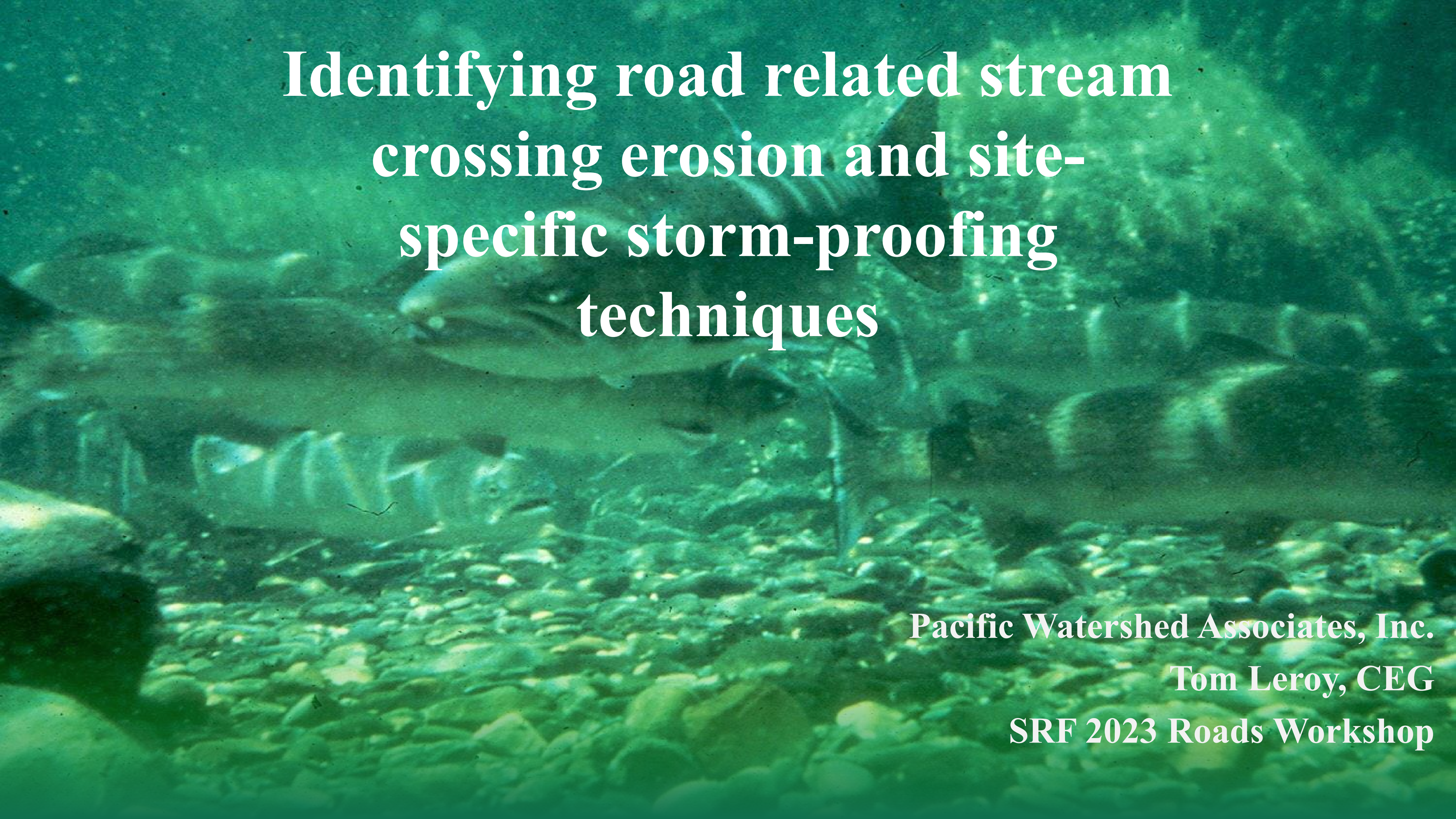
Identifying road related stream crossing erosion and site-specific storm-proofing techniques



Pacific Watershed Associates, Inc.
Tom Leroy, CEG
SRF 2023 Roads Workshop

Road related Sediment Delivery

- Episodic
  - Landslides
    - Cutbank slides
    - Fillslope slides
  - **Stream crossings**
    - Washouts
    - Stream diversions (gullies and hillslope debris slides)
  - Gullies (from road drainage)

- Chronic
  - Hydrologically-connected bare soil areas
    - Road reaches
    - Bare areas (quarries, landings, trails, harvest areas, etc)

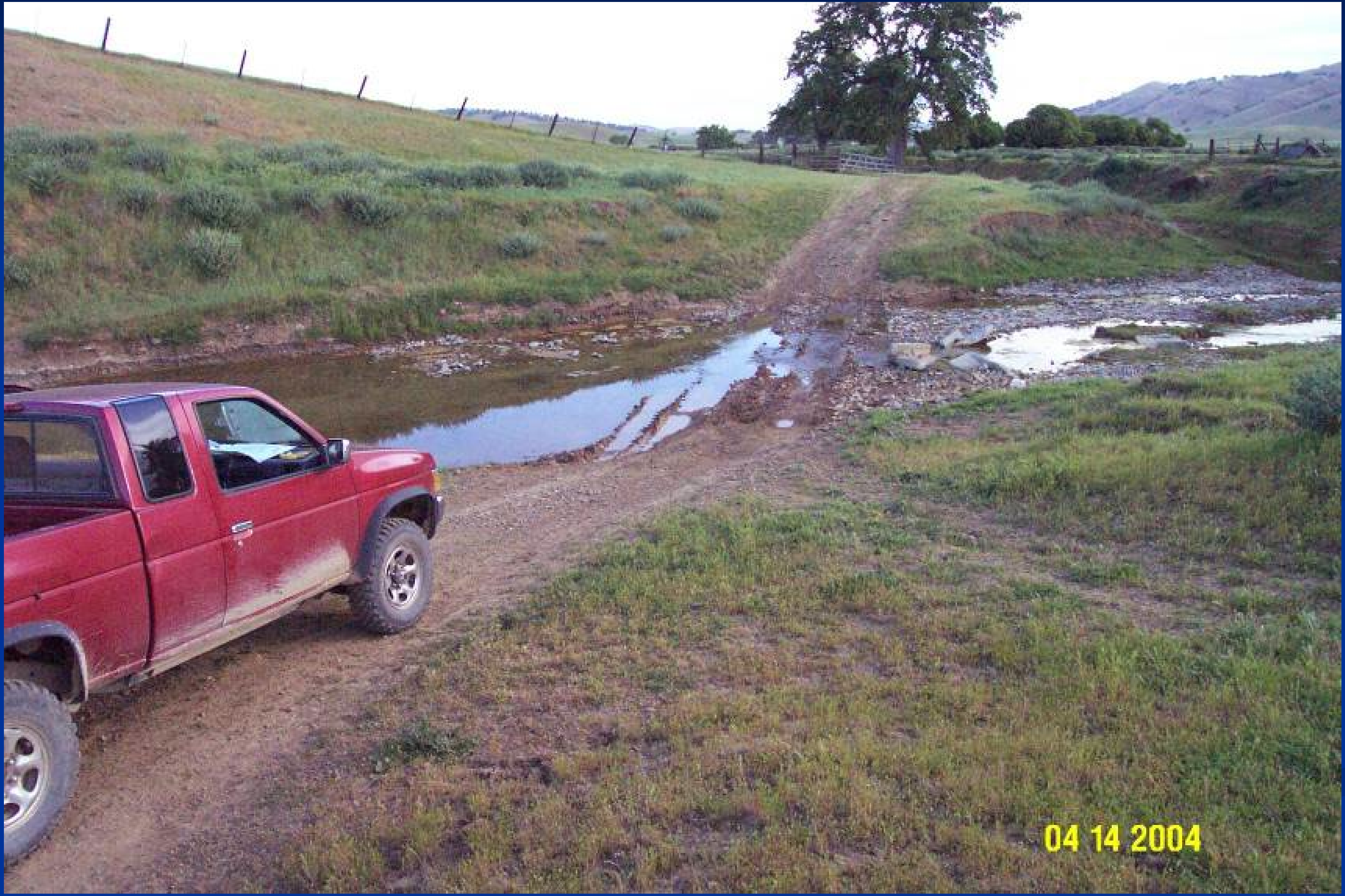
Typical stream crossing configurations and typical problems

Unculverted Stream Crossings

Unculverted Stream Crossings

Hardened Ford

Ford with soft bottom



Culverted stream crossing failures

Wash out (eroded) stream crossing

Stream diversion

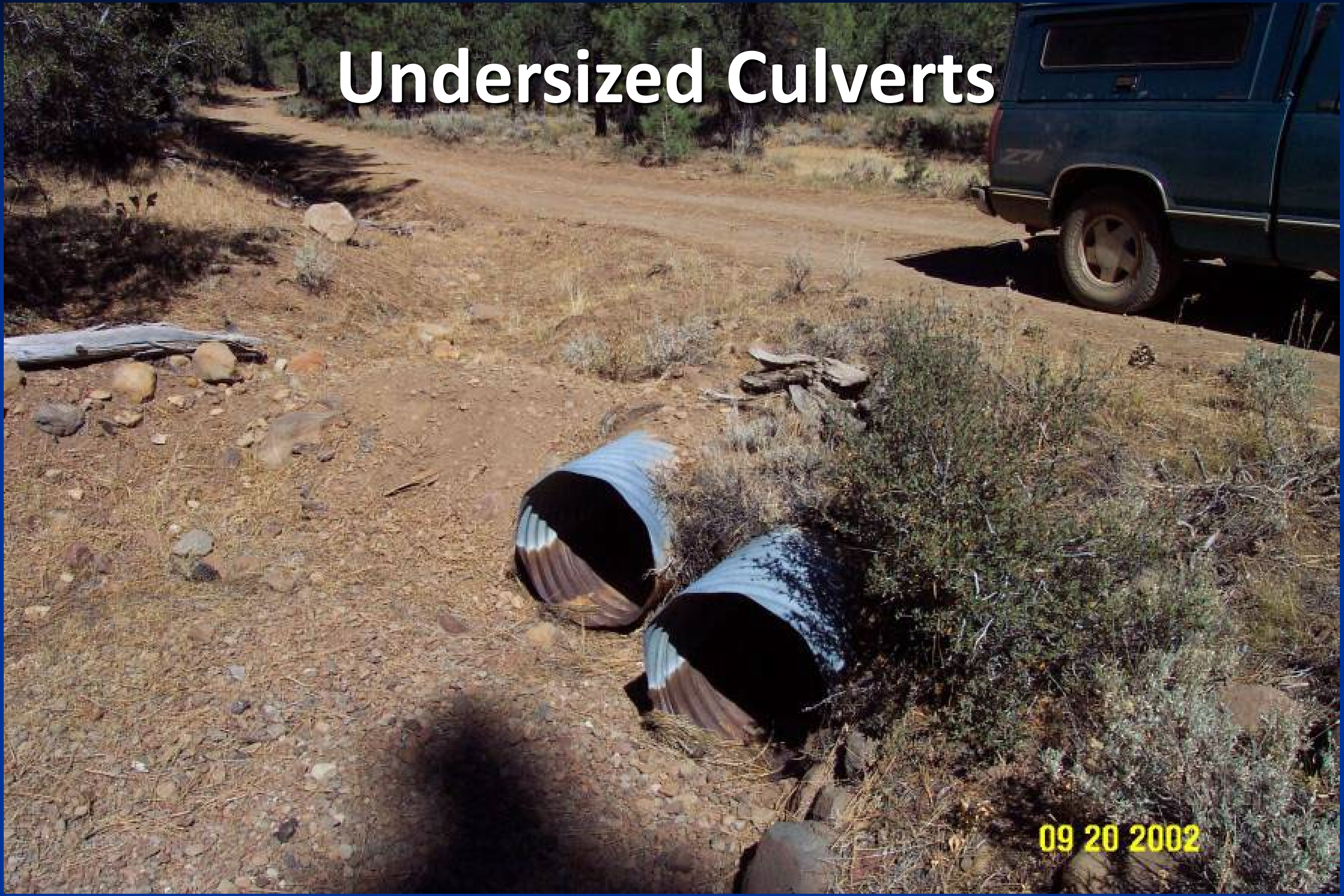
Shallow, Short Culvert

Plugged Culvert – Crossing erosion

Washed Out Stream Crossing

Undersized Culvert

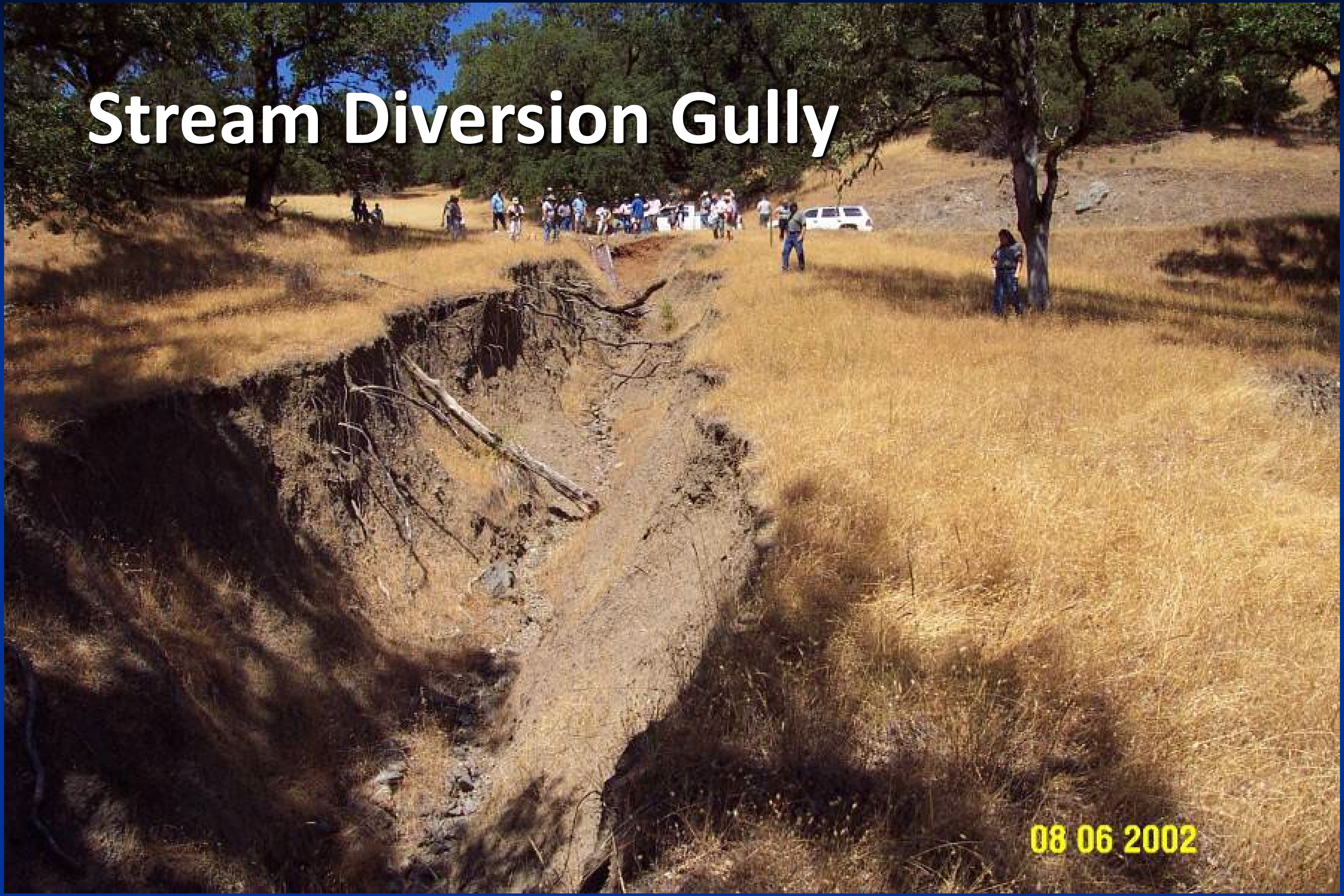
Undersized Culverts



Culvert Plugging

Plate Arch (Poor Orientation)

Stream Diversion


Stream Diversion Gully
08 06 2002

Separated Culvert, Collapsing Fill

Humboldt Crossing, Collapsing Fill

Culvert Plugged from Debris Flow

Rusted-through culvert

Plastic Burns….

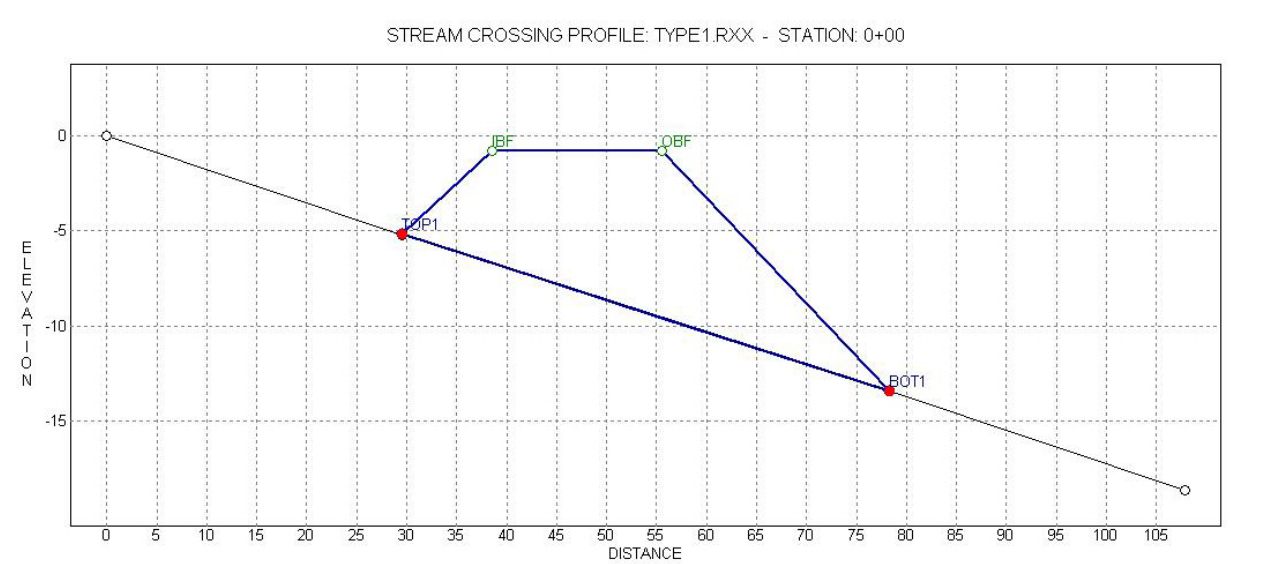
Bridge (insufficient capacity)

Reduced channel width

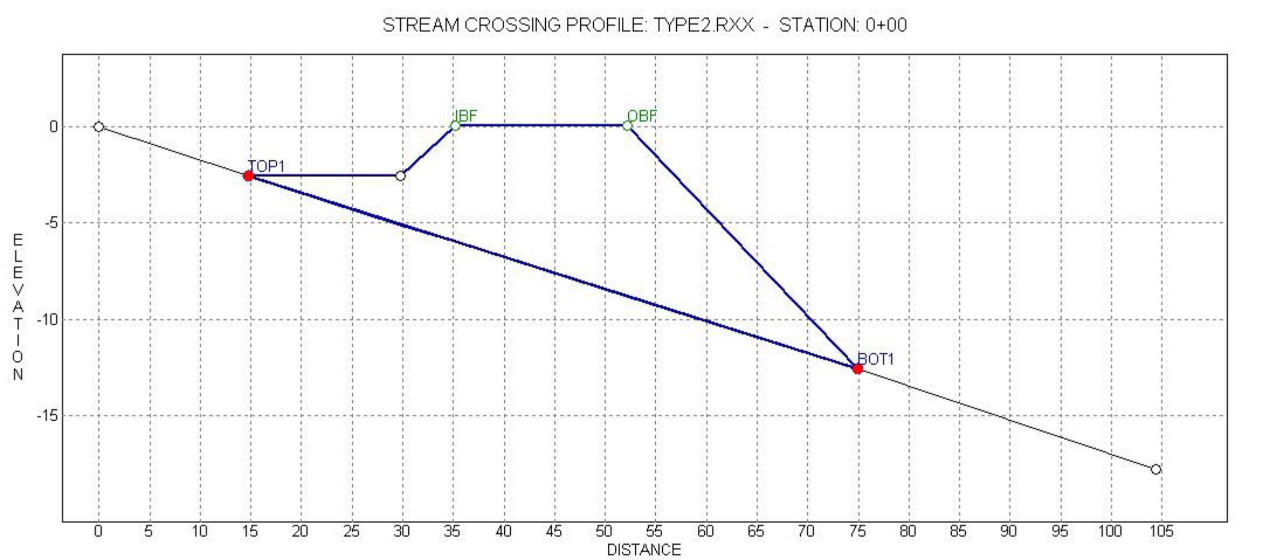
Undercut armor

Estimation of Stream Crossing Fill Volumes

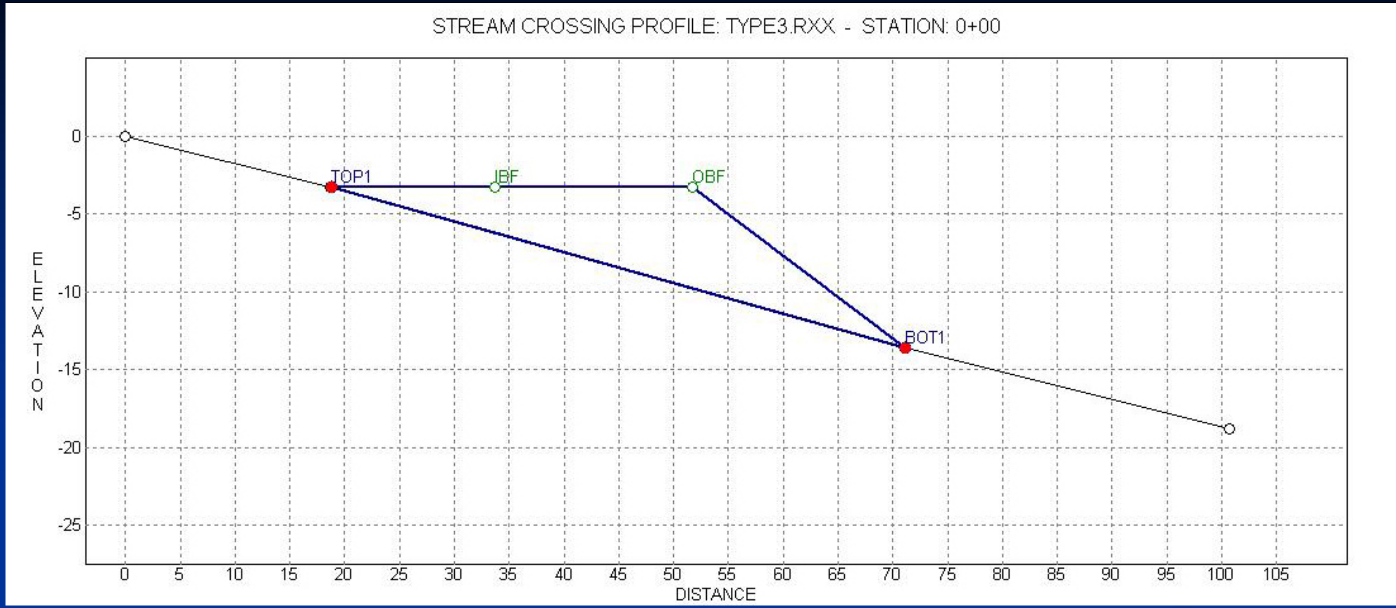
Type 1



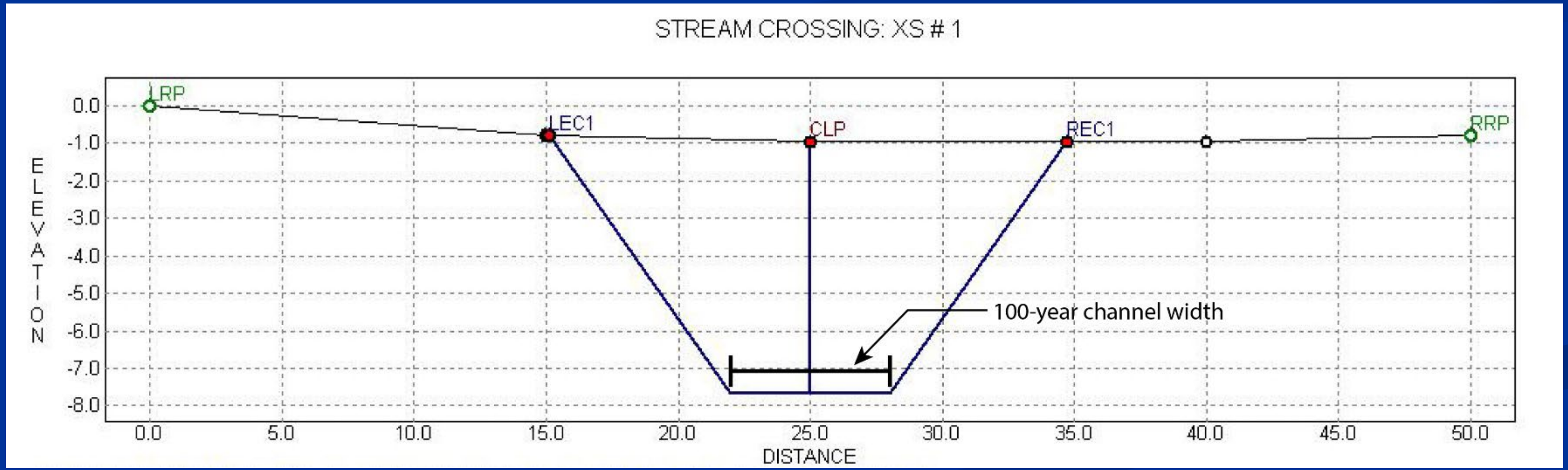
Type 2



Type 3

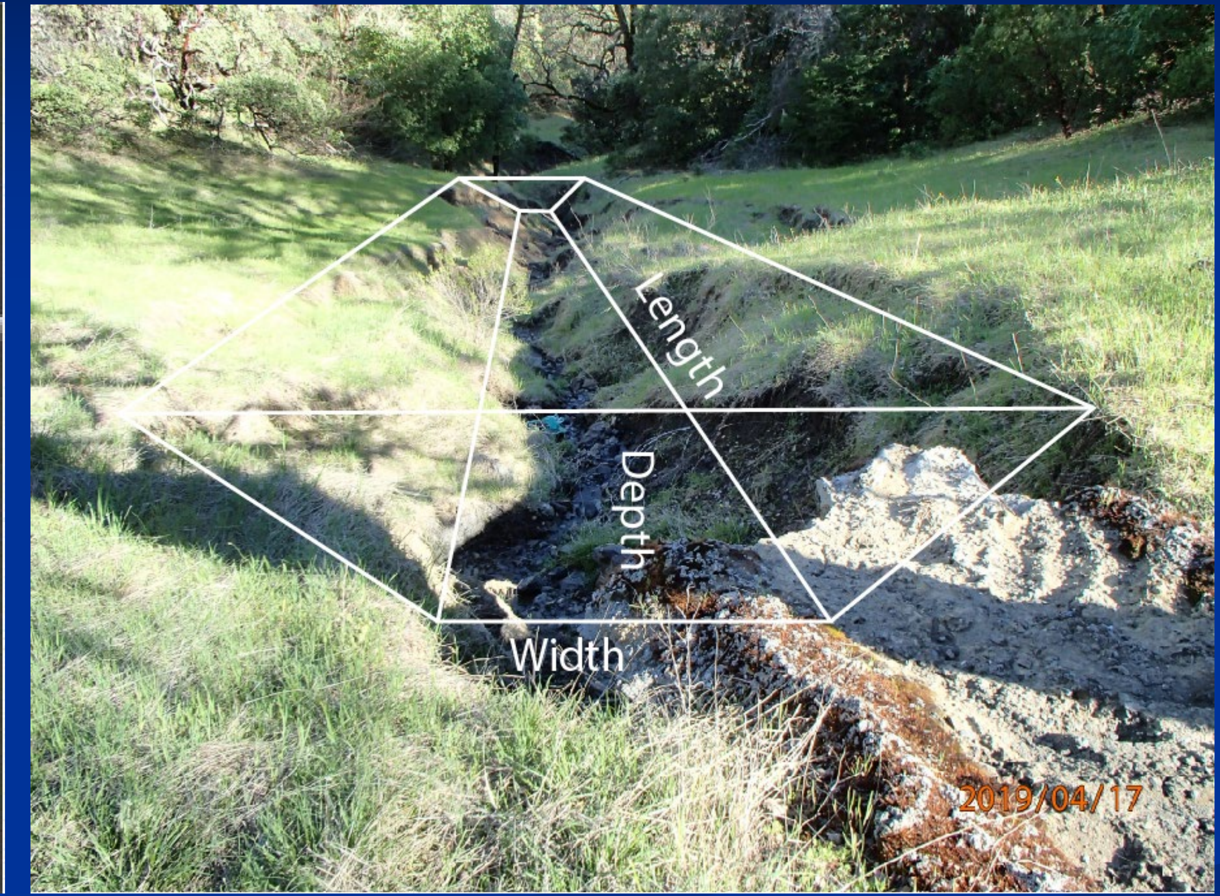


Cross Sections



Stream crossing fill volume standard (Weaver et al., 2006)

Estimating future sediment delivery from other episodic erosion features (landslides, fill failures, and gullies)



Direct measurement of feature length, width, and depth

What to inventory and upgrade…

Note: A forward-looking sediment assessment is <u>essential</u> for identification, quantification and prioritization of sites

- Stream crossings
  - ✓ Culvert capacity (100-yr+)
  - ✓ Plugging potential
  - ✓ Diversion potential
  - ✓ Site erosion (cmp outlet, streambanks, fillslopes, etc)
- Road related landslides
  - ✓ Potential road and landing fill failures
  - ✓ Potential debris slides in steep swales
  - ✓ Larger deeper landslides (1-for-1 rule)
- Road surface runoff and related erosion
  - ✓ Hydrologically connected roads and ditches
  - ✓ Gullies

Treating Road Stream Crossings

What is "Storm-Proofing"

Erosion control and erosion prevention work designed to protect a road, including its drainage structures and fills, from serious episodic erosion during large storms and from chronic erosion during intervening periods.

Types of road storm-proofing

Road Upgrading

Road Decommissioning

Road Upgrading and Watershed Restoration

(face the facts…it must be addressed)

- Open, maintained roads are common and often generate and deliver large volumes of sediment to streams
- Most roads in most watersheds are not abandoned and will be upgraded and maintained for future management
  - decommissioning is comparatively rare
- Most open, maintained roads were built decades ago to now-outdated standards and have weak points that are susceptible to failure
- Most culverted stream crossings are undersized and many have diversion potential
- Most forest roads have high levels of hydrologic connectivity and associated fine sediment delivery

Storm-Proofing Your Roads

- Types of road storm-proofing
- **Objectives and standards**
- Measures of success
- Common techniques

Here's why…

Practical objectives for road upgrading sediment control treatments

- Reduce failure potential (likelihood)
- Reduce failure magnitude (volume)
- Reduce road related sediment delivery
- Lower, more predictable aquatic and water quality impacts
- Lower cost of storm damage repair
- Less time "out of service" after storms –fewer washouts and road failures
- Potential increased ability to work under "wet" conditions – less turbidity
- Increased ability to manage forest resources

Technical Standards: Road Upgrading

- <u>Stream crossings</u>
  - Upgraded for <u>100 year capacity</u>, including organic debris
  - Culvert set on-line and at natural channel grade
  - Plugging potential minimized
  - Diversion potential eliminated
  - Fish passage is accommodated for all life stages
- <u>Road and landing fills</u>
  - Unstable fills that could deliver are <u>excavated/stabilized</u>
  - Spoil is placed where it will not enter a stream
- <u>Road surface drainage</u>
  - Road surfaces and ditches are <u>disconnected from streams</u>
  - Road drainage structures do not drain onto unstable areas

Technical Standards: Road Decommissioning

- Stream crossing side slopes: Excavated and sloped at 2:1 or to the grade of natural side slopes above and below the crossing
- Stream crossing channel profile: Excavated at natural channel grade through the crossing with no abrupt grade changes at the top or the bottom of the excavation – the standard is to exhume original channel bed
- Stream crossing channel width: Excavated to match or exceed the natural channel width outside of the influence of the crossing; the design standard is the 100-year flow width
- Road approaches and all road reaches: Hydrologically disconnected to minimize direct runoff into the crossing or into nearby streams
- Road related fill slope landslides: Fillslope landslides with potential for sediment delivery are excavated and removed

Storm-Proofing Your Roads

- Types of road storm-proofing
- Objectives and standards
- **Measures of success**
- Common techniques

Measures of success

- **Road upgrading – *resiliency & threat reduction***
  - Decreased culvert plugging
  - No unexpected stream diversions
  - Lower frequency of stream crossing washout
  - Lower sediment delivery from crossing failure
  - Lower frequency and delivery from road fill failures
  - Hydrologic connectivity reduced to 10% to 20%, or less

- **Road decommissioning – *eliminate threats***
  - Excavated stream crossings exhibit less than 5%, preferably less than 2%, loss of erodible fill volume
  - Lower frequency & delivery from road fill failures
  - Hydrologic connectivity reduced to less than 5%

Storm-Proofing Your Roads

- Types of road storm-proofing
- Objectives and standards
- Measures of success
- **Common techniques**

Road Upgrading Treatments

Four Road Upgrading Treatment Mantras

1) Treat sites of sediment delivery
2) Treat the cause, not the symptom
3) If you don't change anything, it's just going to happen again
4) Prevent erosion before you have to try to control it

Erosion versus sediment delivery:

1) Treat sites of sediment delivery

2) Treat the cause, not the symptom

3) If you don't change anything, it's just going to happen again…

4) Prevent things from happening in the first place!

1) Treating Stream Crossings

Reducing stream crossing vulnerability

- **Culverted stream crossings** are naturally susceptible to failure. Failures include:
  - Plugging and overtopping
  - Washout (erosion from various causes)
  - Stream diversion*
- **Bridges and fords** are usually designed to minimize failure potential

**Stream diversions cause from 2 to 10 times the volume of erosion and downstream sediment delivery (through gullying and landsliding) compared to simply eroding and washing out a stream crossing fill.*

Methodologies for estimating design storm discharge (Q_{100})

- Rational method equation – drainage basins 80 acres and less
- Magnitude and frequency method – drainage basins larger than 80 acres
- Flow transference – uses discharge records from a nearby hydrologically comparable gaged basin

Rational Method equation

$$Q_{100} = C\ I\ A$$

Q_{100} = predicted peak runoff from a 100-year storm (cfs)
C = runoff coefficient
I = rainfall intensity for the 100-year storm (in/hr)
A = drainage basin area in acres

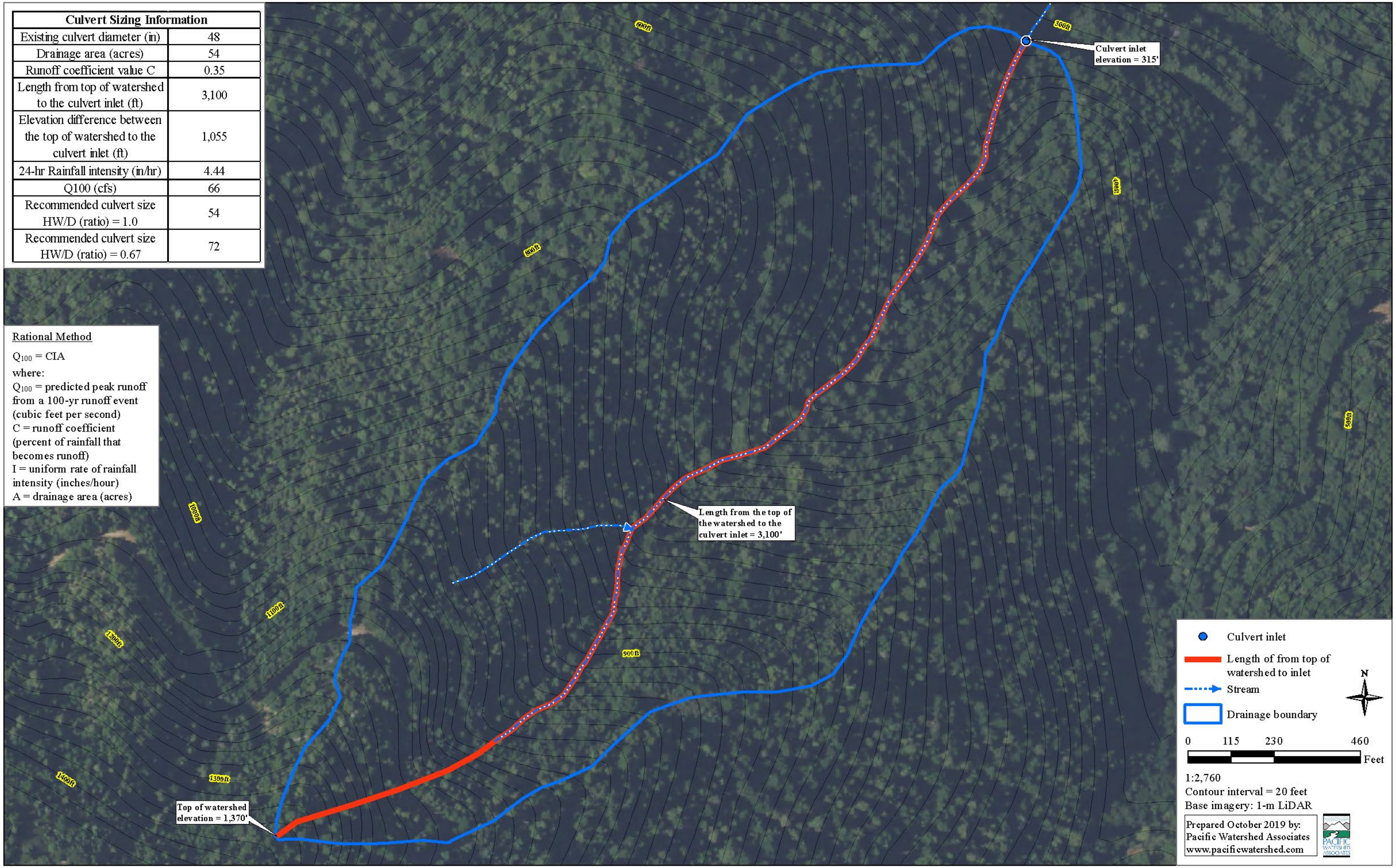
Culvert Sizing Information	
Existing culvert diameter (in)	48
Drainage area (acres)	54
Runoff coefficient value C	0.35
Length from top of watershed to the culvert inlet (ft)	3,100
Elevation difference between the top of watershed to the culvert inlet (ft)	1,055
24-hr Rainfall intensity (in/hr)	4.44
Q100 (cfs)	66
Recommended culvert size HW/D (ratio) = 1.0	54
Recommended culvert size HW/D (ratio) = 0.67	72

Rational Method

Q_{100} = CIA

where:

Q_{100} = predicted peak runoff from a 100-yr runoff event (cubic feet per second)
C = runoff coefficient (percent of rainfall that becomes runoff)
I = uniform rate of rainfall intensity (inches/hour)
A = drainage area (acres)



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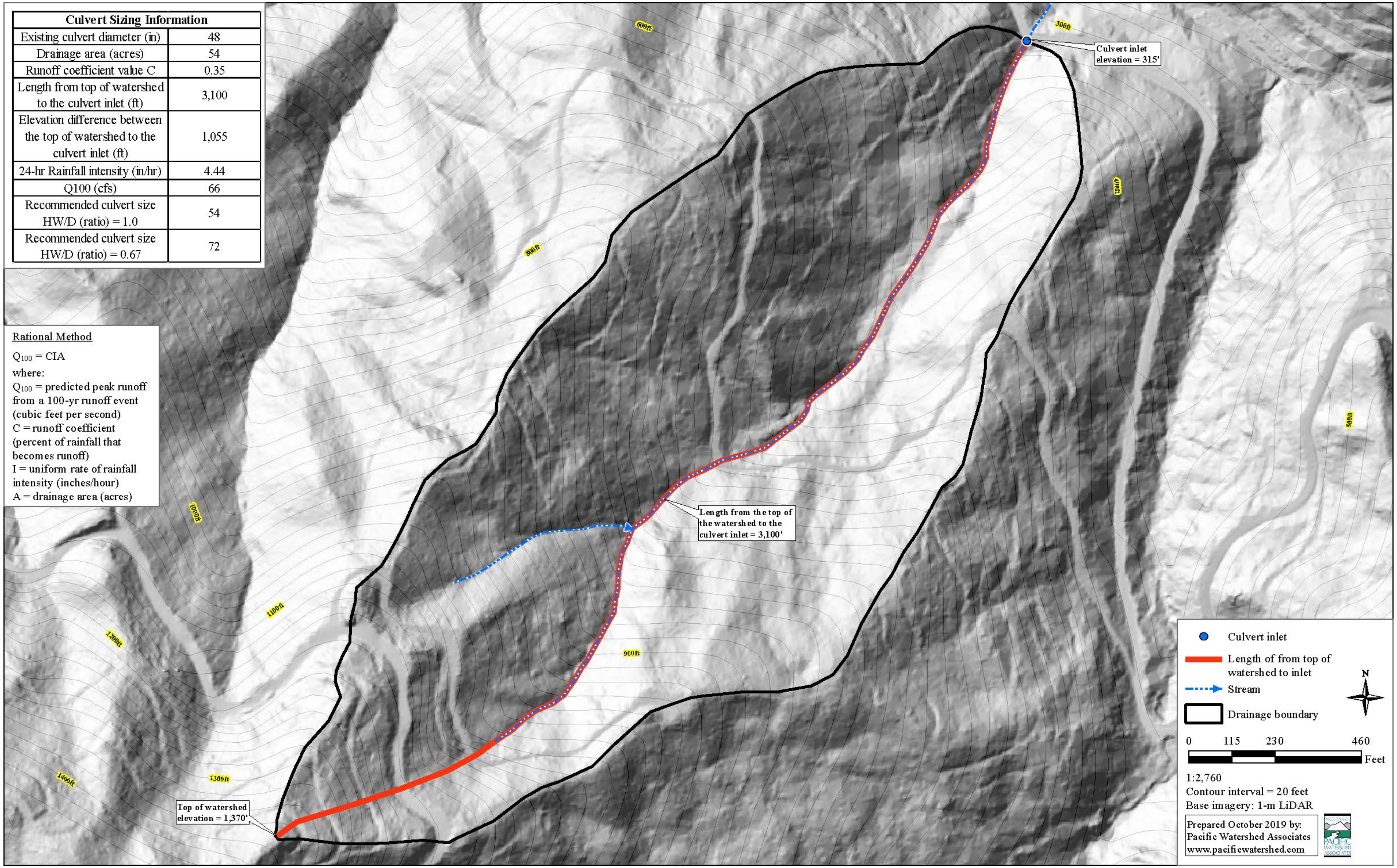


Updated USGS Magnitude and Frequency Method

(Gotvald et al., 2012)

Q_{100} = predicted 100-year flow (cfs)
A = area draining to crossing (mi^2)
P = mean annual precipitation (in)
H = mean basin elevation (ft)

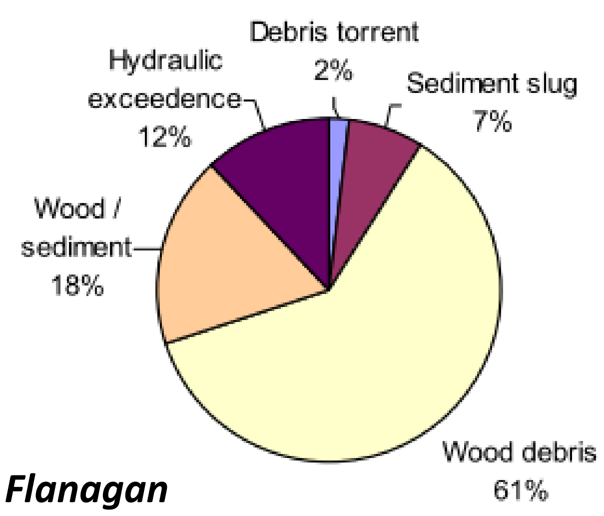
North Coast	$Q_{100} = 48.5\ A^{0.866}\ P^{0.556}$
Sierra Nevada	$Q_{100} = 20.6\ A^{0.874}\ P^{1.24}\ H^{-0.250}$
Lahontan	$Q_{100} = 0.713\ A^{0.731}\ P^{1.56}$
Central Coast	$Q_{100} = 11.0\ A^{0.840}\ P^{0.994}$
South Coast	$Q_{100} = 3.28\ A^{0.891}\ P^{1.59}$
Desert	$Q_{100} = 1350\ A^{0.506}$

Post-fire sediment loading

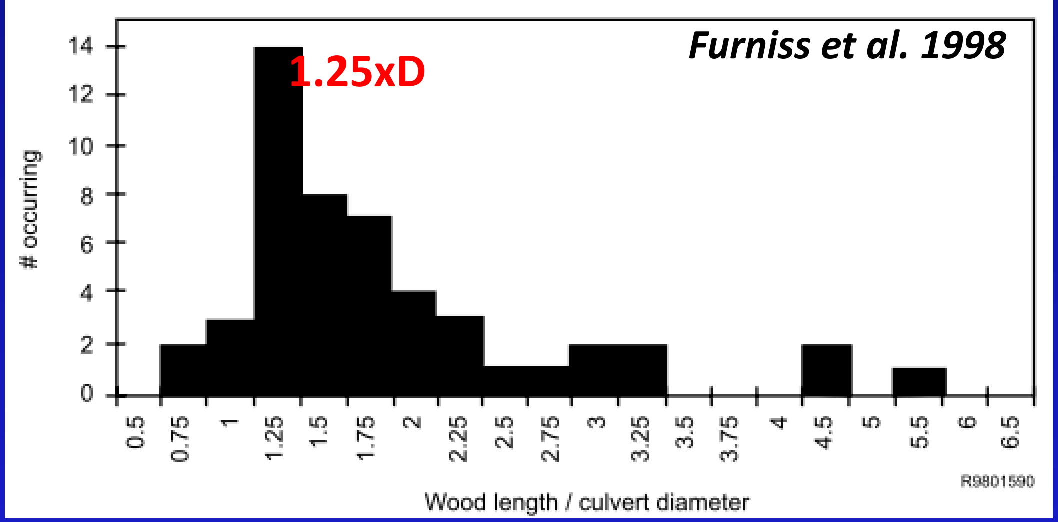
Predict, prevent, mitigate

Sizing culverts for peak flows,

…including sediment and debris



- Increase culvert diameter to account for debris (so HW/D = 0.67) (per Cafferata, et al. 2004)
- Install a wider culvert (oval or arch)
- Install flared or mitered inlet
- Install trash barrier or deflector
- Install overflow culvert or snorkel
- Install arch or bridge



Reducing stream crossing vulnerability

New culverts can be **sized** and **designed** (shaped) to reduce the risk of plugging.

In-channel and **drainage structure** treatments can be applied to new and *existing culverted stream crossings* to reduce the chance that a culvert will become plugged, with subsequent flood flows overtopping or diverting down the road.

Culvert replacement at base of fill

Culvert replacement at base of fill

Culvert replaced in alignment of stream channel

Reducing stream crossing vulnerability

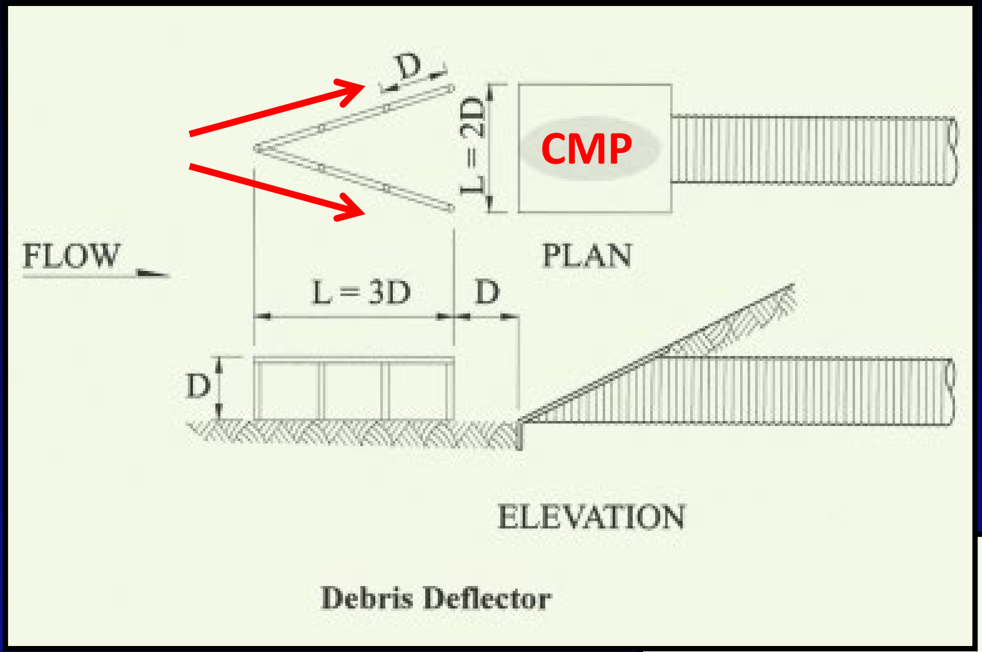
Common techniques for reducing the risk of stream crossing failure:

- Culvert upsizing
- Culvert widening (width and shape)
- Installing wingwalls, flared inlets, mitered inlets and/or beveled inlets
- Installing debris barriers or debris deflectors
- Installing emergency overflow culverts and/or snorkels
- Replacing the culvert with a bridge
- Decommission (abandon) the crossing

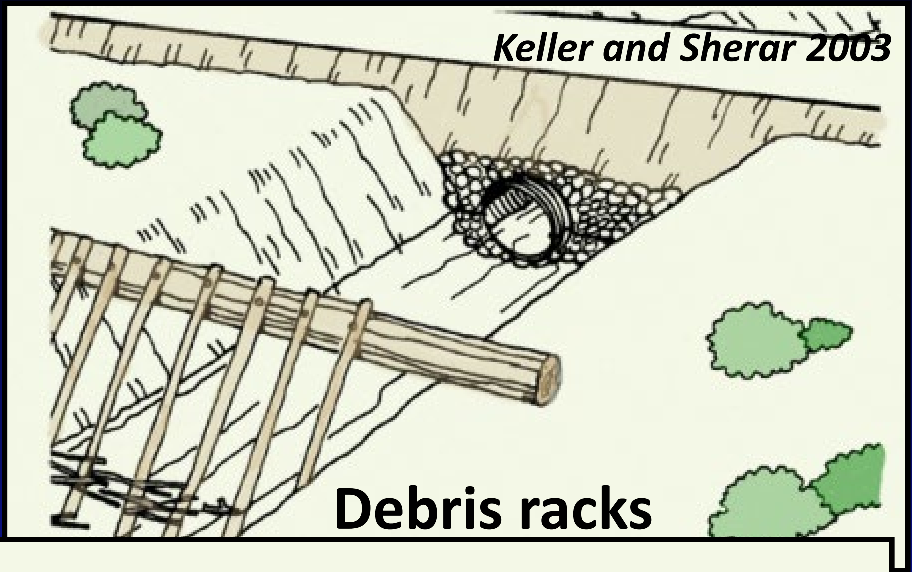
Culvert with single post trash rack

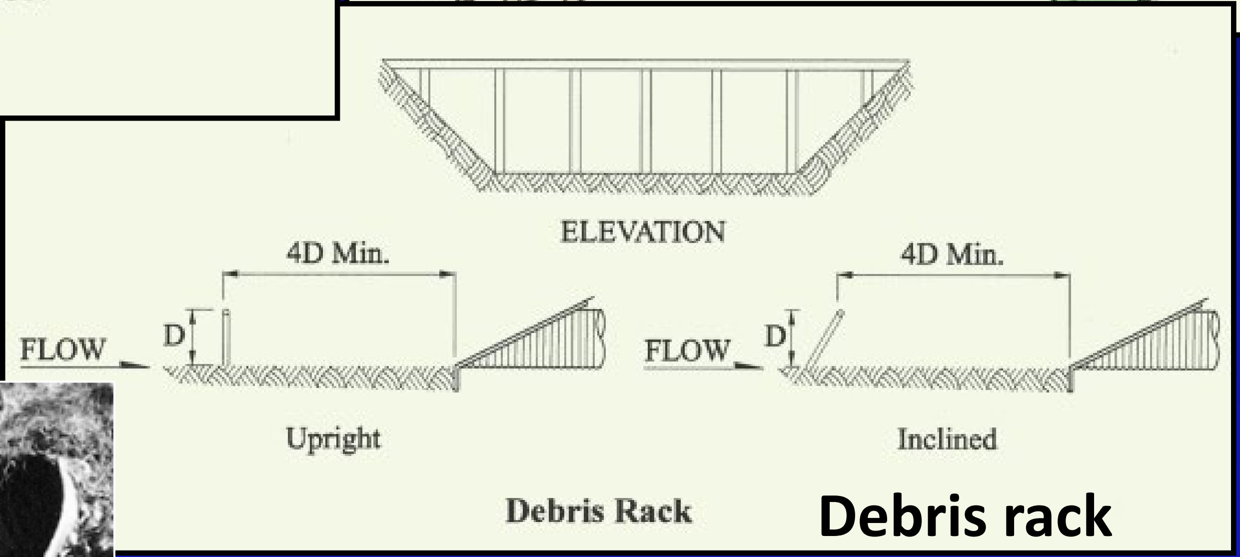
Some measures used to reduce the risk of crossing failure

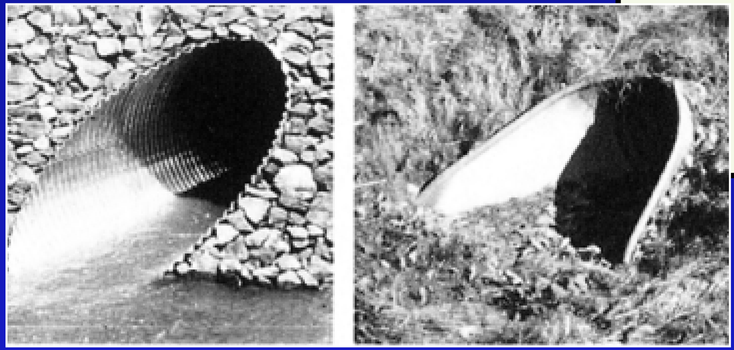
Reducing the risk of stream crossing failure



Debris deflector







Mitered and flared inlet

Reducing the risk of failure

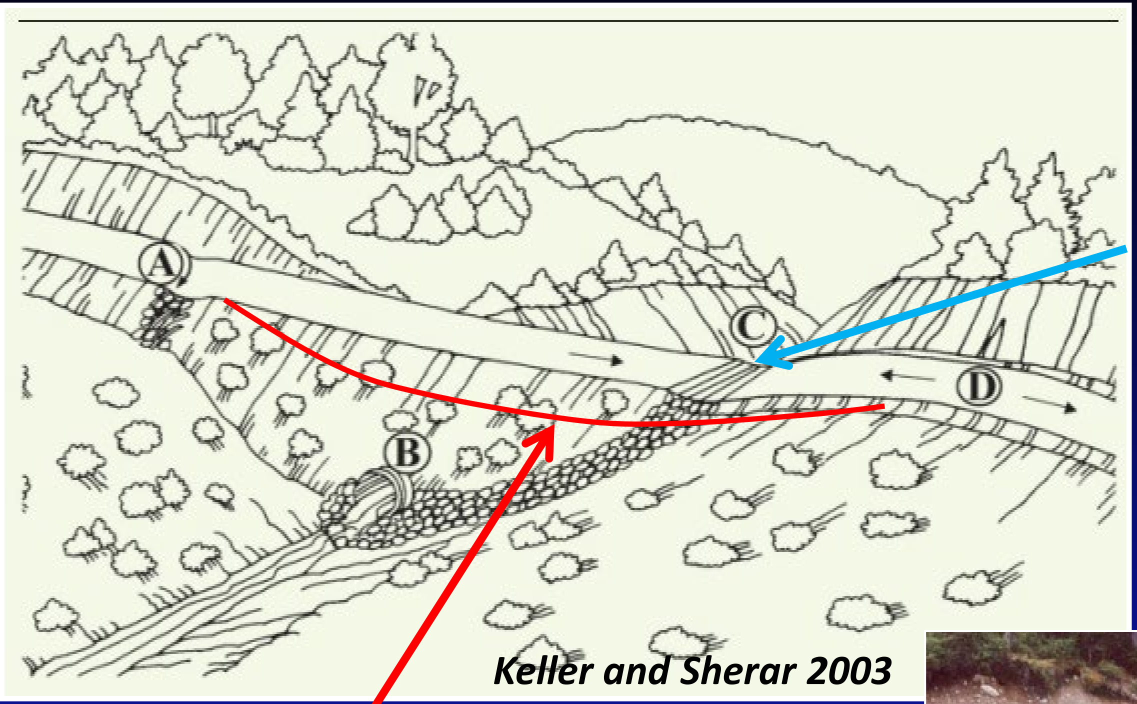
Culvert upsizing

Reducing stream crossing vulnerability

Common techniques for reducing the risk of stream diversion:

- Install a critical dip (properly designed)
- Dip the entire stream crossing fill (lower the fill)
- Install an emergency overflow culvert, with downspout

Reducing (eliminating) risk of stream diversion



Critical dip

Lowered fill

Critical dip

Predict, prevent, mitigate

Reducing stream crossing vulnerability

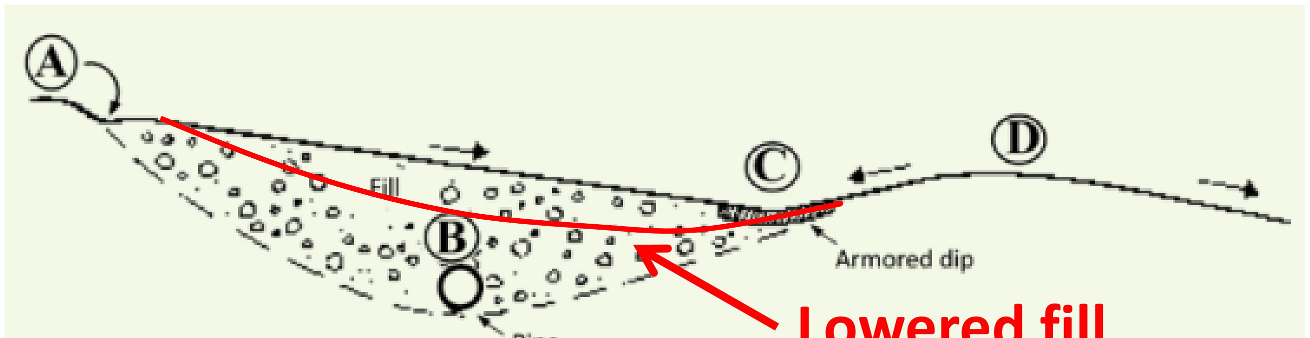
Common techniques for reducing the magnitude of stream crossing failures:

- Minimize the erodible fill volume (dip or lower the entire crossing fill)
- Minimize overtopping erosion rates (ensure overtopping occurs at a hardened or resistant location – usually the down-road hingeline)
- Armor or harden the overflow spillway (armor the axis of the overflow dip, down the fill face (used only where overtopping is common))

Reducing the magnitude of crossing failure

Reducing erodible fill volume

Reducing overtopping erosion rates



Keller and Sherar 2003

Fish passage at stream crossings

Preferred stream crossing designs for fish-bearing streams (NMFS):

- **Preferred** - No stream crossing structure (find another place for the road or decommission the existing crossing)
- Bridge (channel spanning)
- Bottomless arch, embedded culvert, embedded or high VAR vented ford (channel width with natural streambed)
- Non-embedded culvert or hydraulic design (low gradient channels only)
- **Least preferred** - On steeper gradient channels, install baffled culvert or a structure with a designed fishway.

Embedded culvert upgrade for fish passage

Bridge installation to facilitate fish passage

Predict, prevent, mitigate

Stable stream crossing fills

Designing stable stream crossing fills:

- Avoid clay rich or cohesionless soils
- Fills should be compacted during optimal moisture content (moist) in 6” to 12” lifts; Fill face compaction is achieved through excavation of the compacted fill
- Vibratory rollers are used for low cohesion soils, sheeps foot rollers for cohesive soils, and mechanical tampers for cohesive soils along the culvert bed and flanks; *Field compaction* using rubber tired equipment and dozer tracking may be acceptable under ideal moisture conditions
- Strive for fillslope angle less than 1½:1, preferably 2:1 or less, or buttress/armor the slope
- Revegetate fillslopes, divert road surface runoff, and armor culvert outlet and fillslopes where necessary (steep fillslopes)

Stable stream crossing fills

Vegetated 2:1 fillslope with extended culvert outlet and minimal armor

Armored 1:1 fillslope, with dense internal compaction, on steep Class III channel

Fillslope buttressing and barrel projection

Predict, prevent, mitigate

Stream crossing culverts

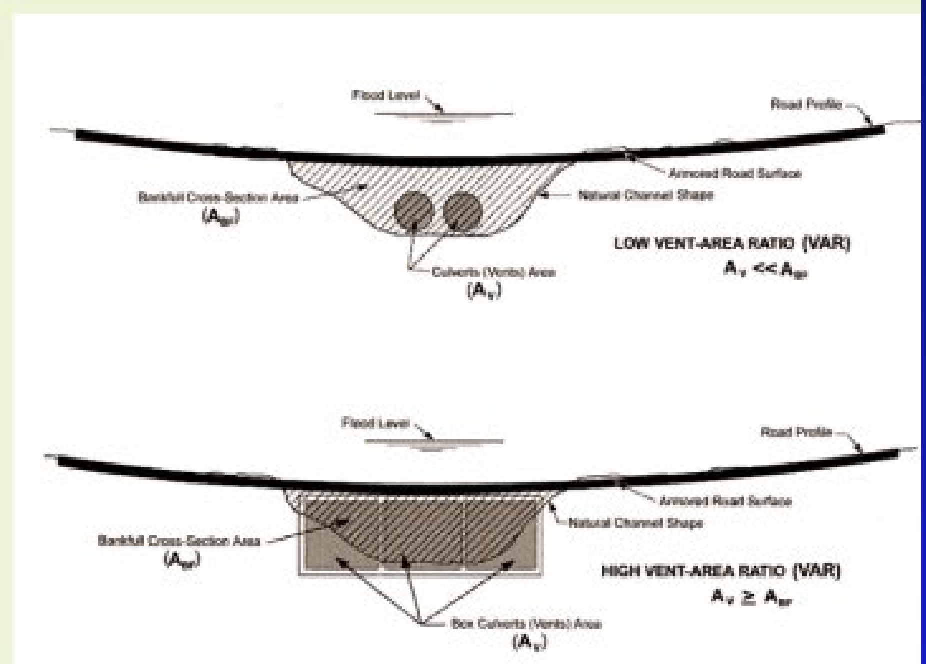
- **Culvert materials**: steel, aluminum, concrete, plastic
- **Durability**: abrasion, corrosion
- **Sizing**: Rational, USGS Magnitude and Frequency, Flow transference
- **Alignment and length**: vertical, horizontal
- **Debris treatments**: Debris rack (barriers and screens), debris deflectors, risers
- **Inlet treatments**: mitered inlet, tapered inlet, flared inlet, beveled inlet, slope collars, headwalls, snorkels, risers
- **Emergency overflow culverts:** sizing and design

Other stream crossing structures

- Bridges: Log stringer (no longer common), I-beam (engineered), truss (Bailey)(up to 200'), and rail car (up to 90')
- Armored fills and vented fills
- Fords (native), hardened fords, and vented fords
- Temporary stream crossings (fill, culverted fill, log, and bridge)

Other stream crossing structures

Other stream crossing structures



(Keller and Ketcheson, 2012)

Armored fill crossings

Armored fill crossings

Armored fill with large diameter rock

Armored fill displaying adequate keyway cross section


CAT
CAT
330


Special considerations in Upgrade Treatments

- Paved roads
- County Roads (paved/unpaved public roads)
- Main Line USFS roads (paved and unpaved)
- Roads in the snow zone
- Steep roads (>~12%)
- Road use types and levels (speed and clearance restrictions; e.g., lowboys, FedEx and BMWs; commercial roads vrs subdivision roads)
- Stream crossings in debris flow channels

SUMMARY
Measures of Success for Road Upgrading Treatments

- **Road upgrading**
  - Decreased culvert plugging
  - No unexpected stream diversions
  - Lower frequency of stream crossing washout
  - Reduced sediment delivery from crossing failures
  - Lower frequency and delivery from road fill failures
  - Hydrologic connectivity reduced to 10% to 15%, or less!

Poor rock armor application

Road Decommissioning

Common Techniques: Road Decommissioning

1) Ripping or decompaction
2) Cross-road drain construction or outsloping
3) Excavation of unstable fillslopes
4) Stream crossing removal
5) Endhauling and spoil disposal

Road Decommissioning Heavy Equipment

Ripping and decompaction

Decommissioned Road

Decompaction or Road Ripping:

✓Increases infiltration

✓Reduces runoff

✓Promotes vegetation

Road Decommissioning

Cross road drains

Decommissioned forest road

Road ripped and cross-road drained

(straw mulch was added to improve microclimate & promote revegetation)

Excavate unstable fill

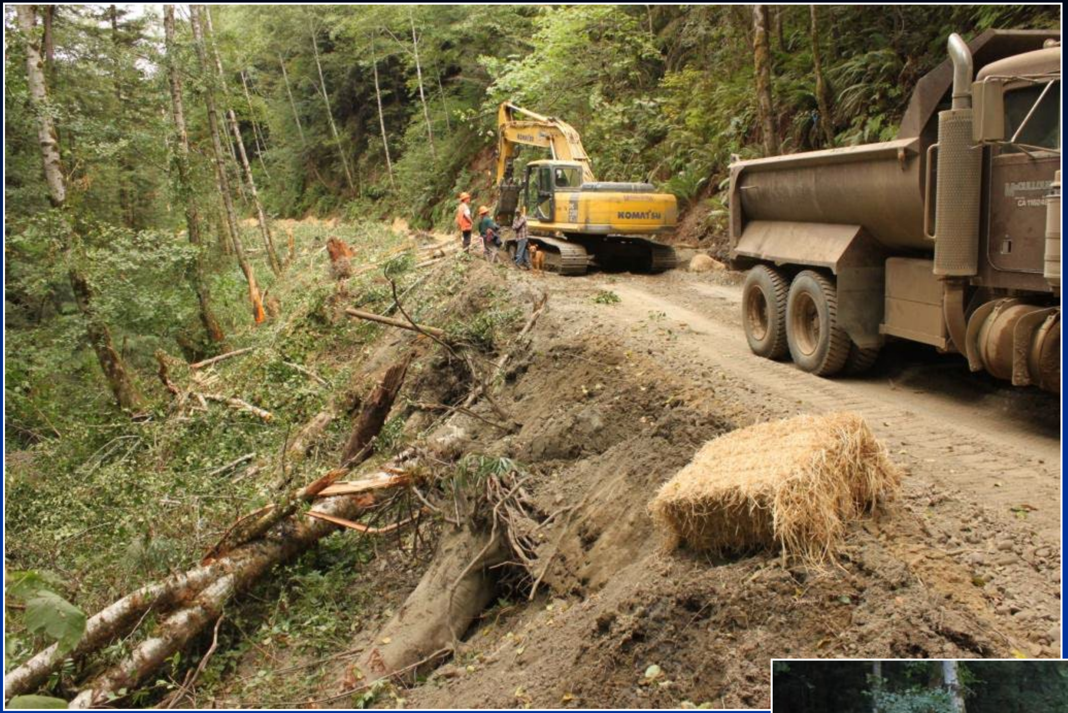
(local spoil disposal against cutbank)

In-Place Outsloping

Local spoil disposal

In-place outsloping

(local spoil disposal)



Export Outsloping

(spoil endhauled)

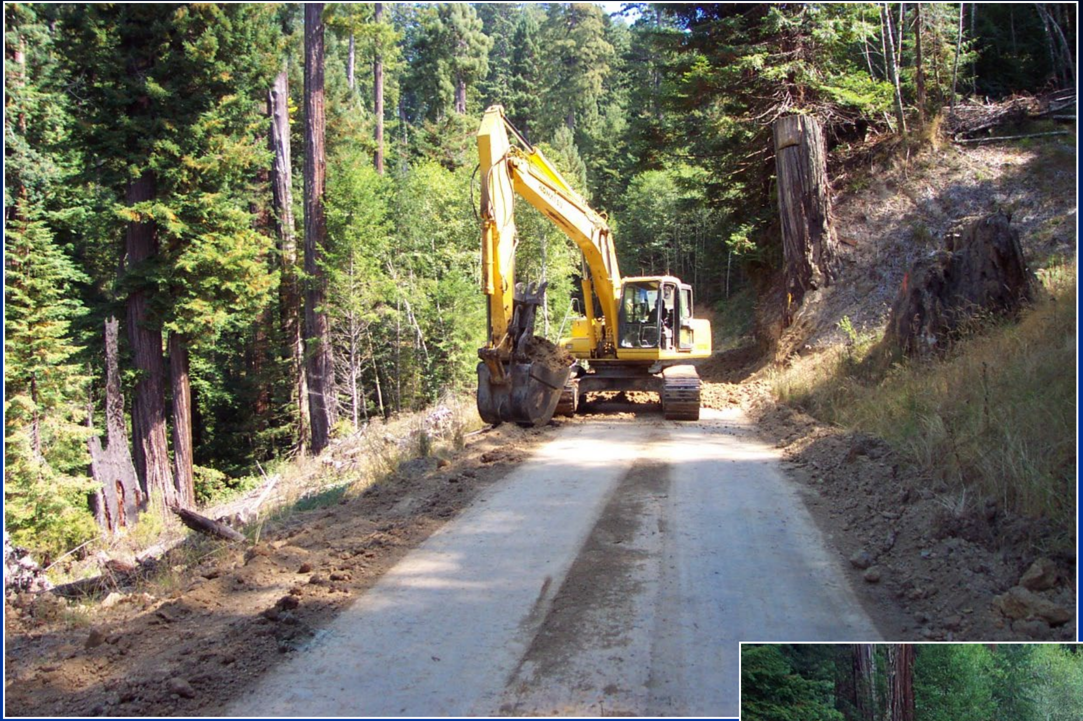
Import outsloping

(spoil hauled to site and used to outslope stable road)

Road erosion treatments – decommissioning

Trail outsloping (road to trail conversion)

Trail outsloping (road to trail conversion)



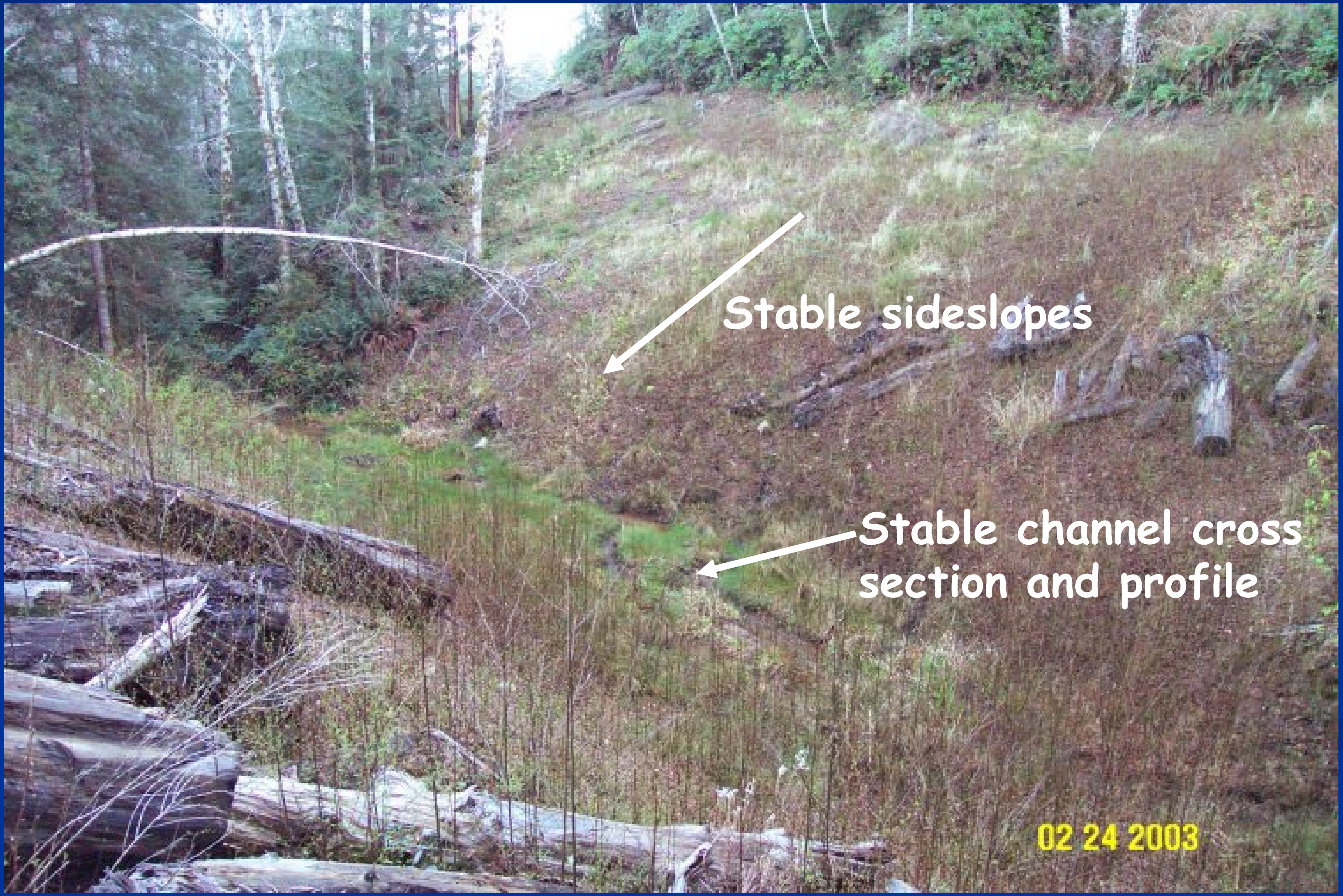
Trail outsloping (road to trail conversion)

Road Obliteration

(total recontouring)

Stream Crossing Decommissioning

(small = <250 yd^3)



Stream Crossing Decommissioning
(medium=250-500 yd^3)

Before

After

Decommissioned stream crossing
(large = >500 yd^3)

Decommissioned stream crossing (large)

Decommissioned stream crossing (large)

Decommissioned stream crossing (large)

Decommissioned Class I stream crossing

(fish passage)

Unstable road
and landing
fillslope excavation

Measures of success for Road Decommissioning Treatments

- **Road decommissioning**
  - Stream crossing decommissioning prevents at least 95% of predicted erosion and sediment delivery.
  - Decommissioning results in a lower frequency & delivery from road fill failures
  - Hydrologic connectivity is reduced to less than 5%

Typical errors in road decommissioning

Potential Problems: Bank Erosion and Channel Downcutting

Insufficient channel width

Incomplete excavation

Problems: Side Slope Failures

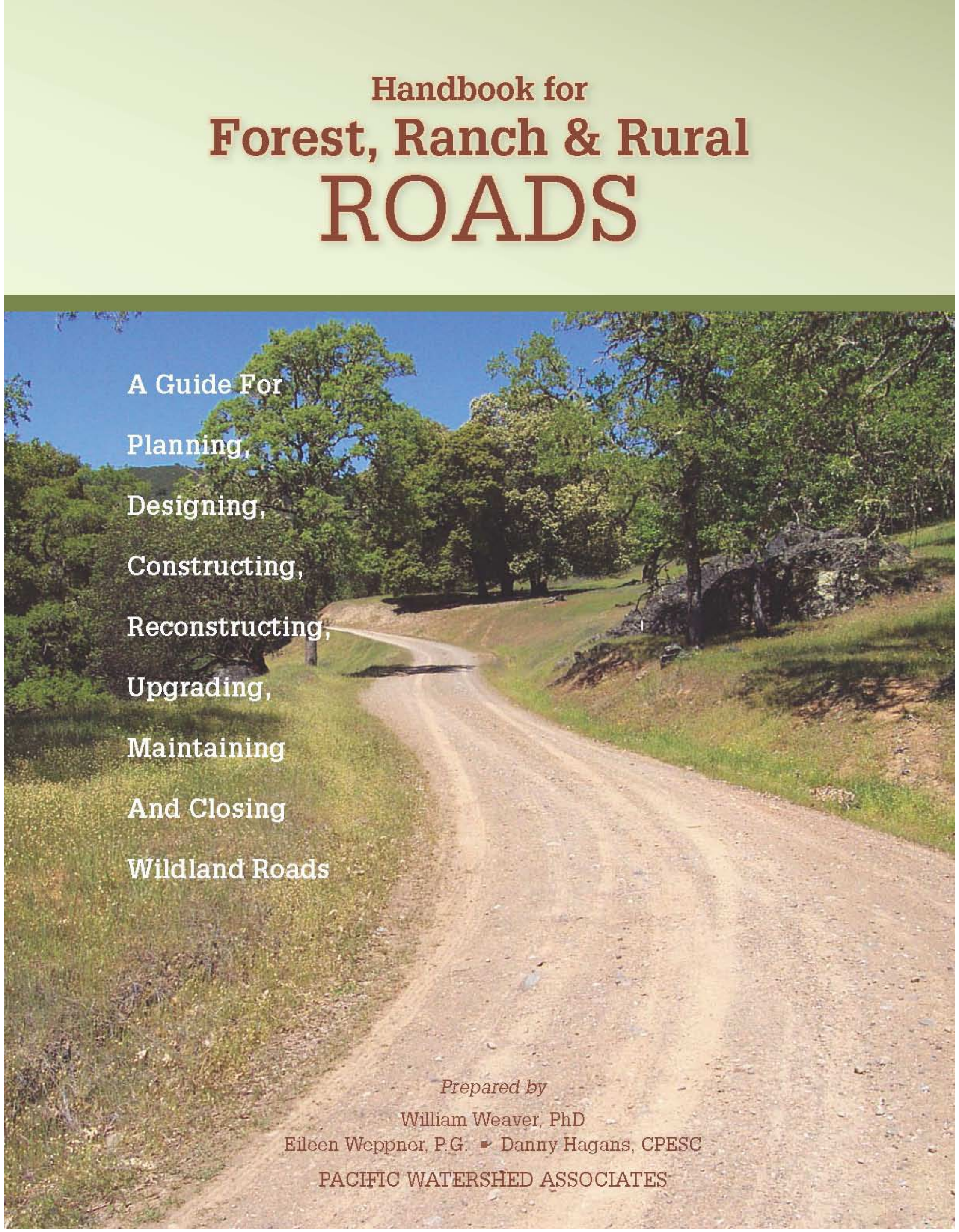
Spoil disposal on sideslopes of decommissioned stream crossing

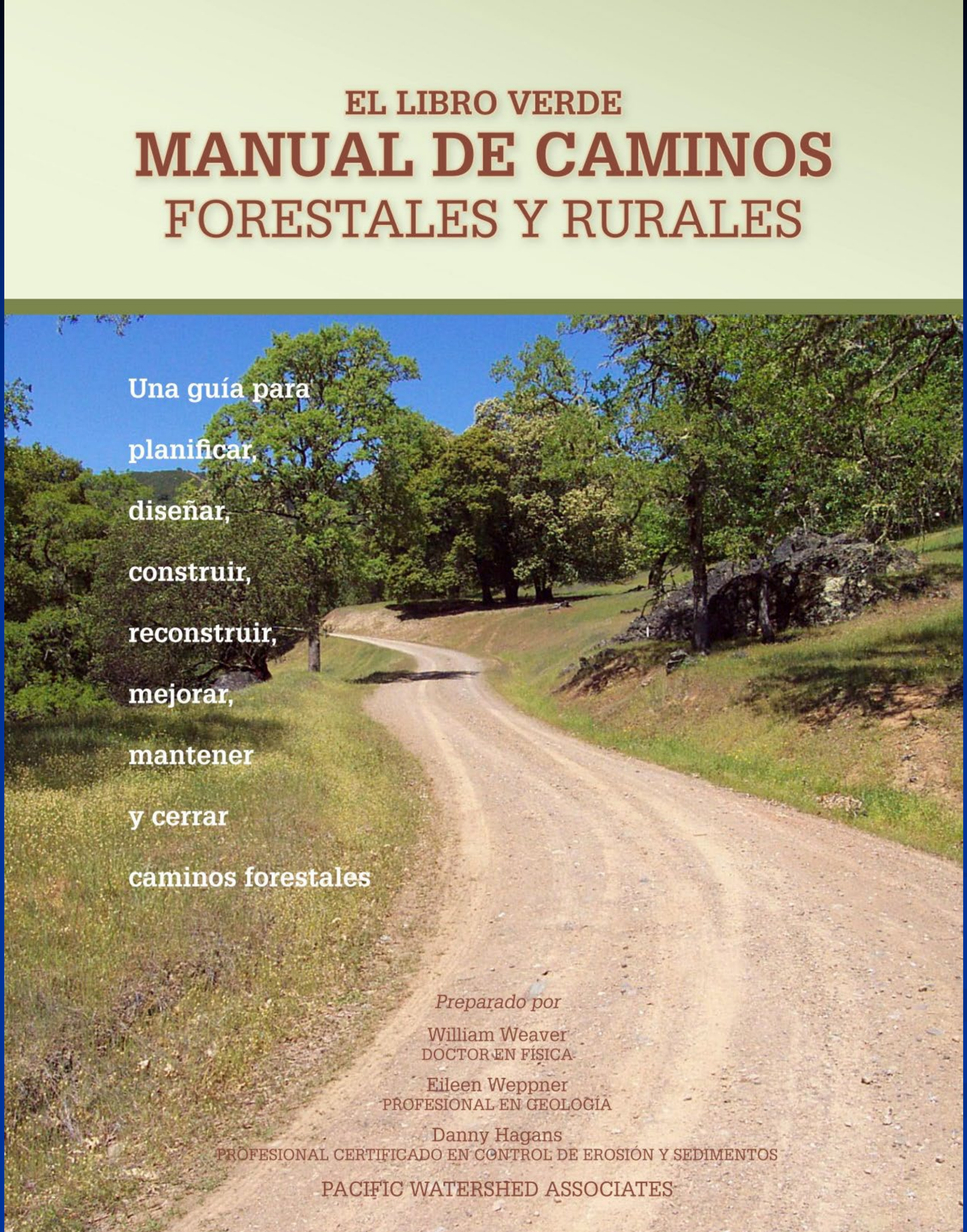
Additional Resources

Handbook for Forest, Ranch and Rural Roads:

Focus on stream crossings and hydrologic connectivity

William Weaver
Pacific Watershed Associates

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Una guía para
planificar,
diseñar,
construir,
reconstruir,
mejorar,
mantener
y cerrar
caminos forestales
Preparado por
William Weaver
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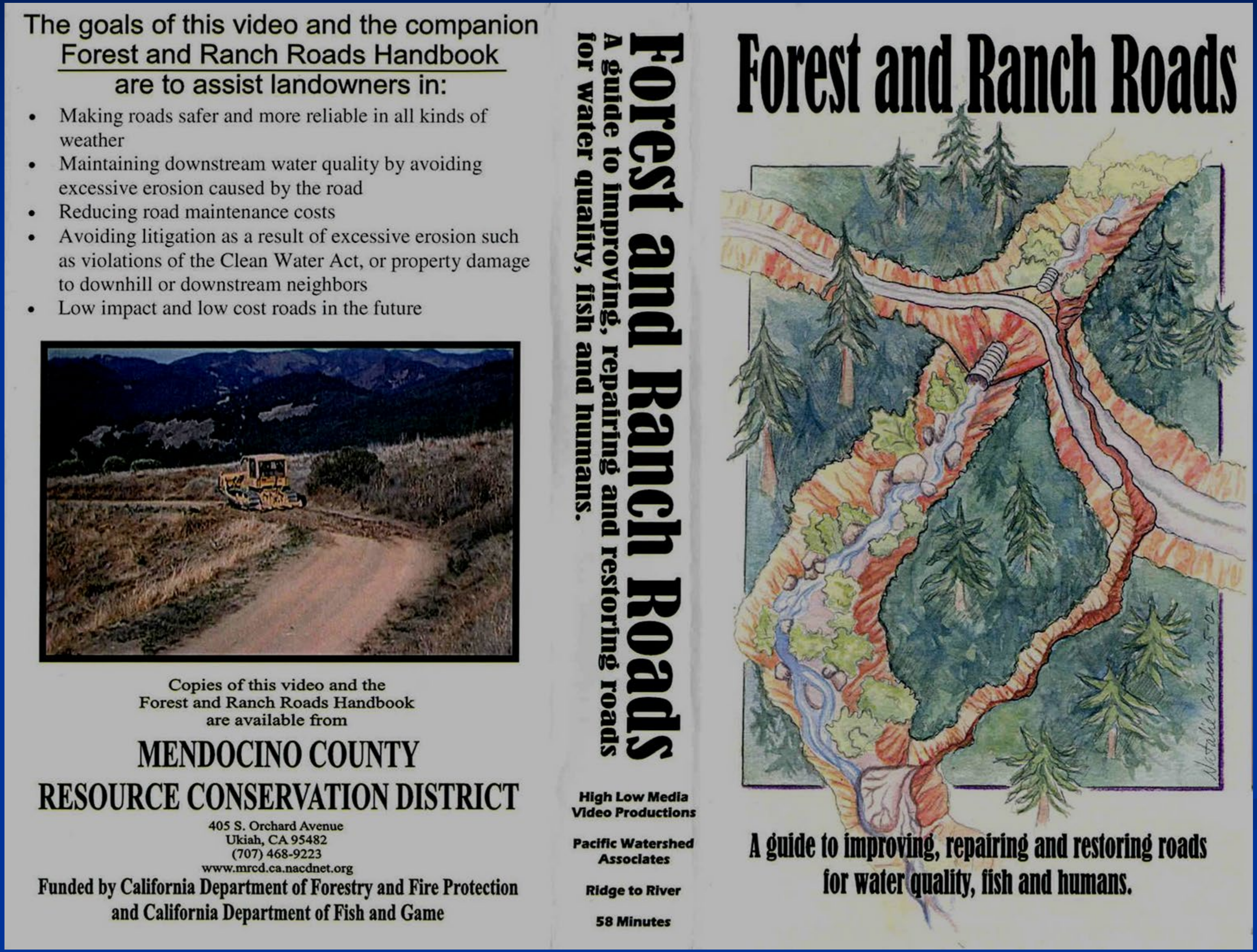
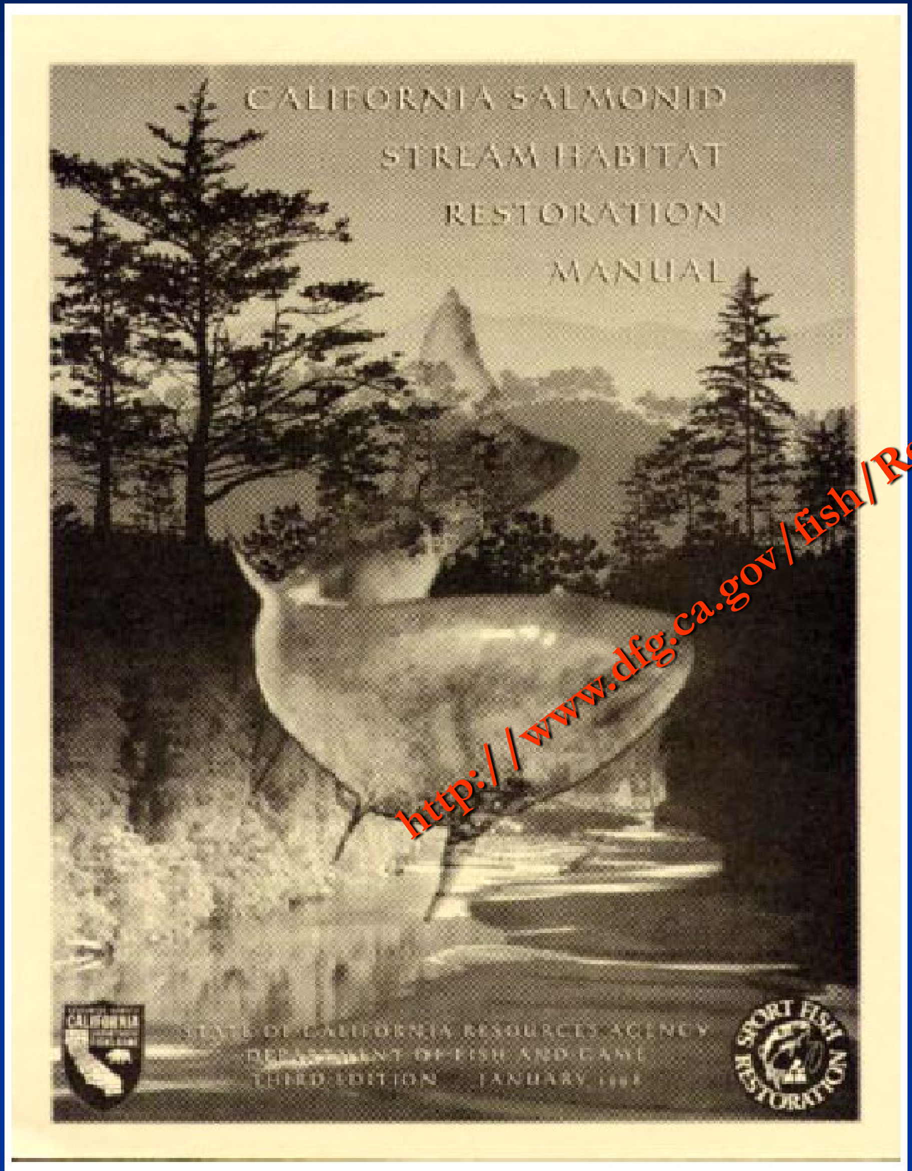
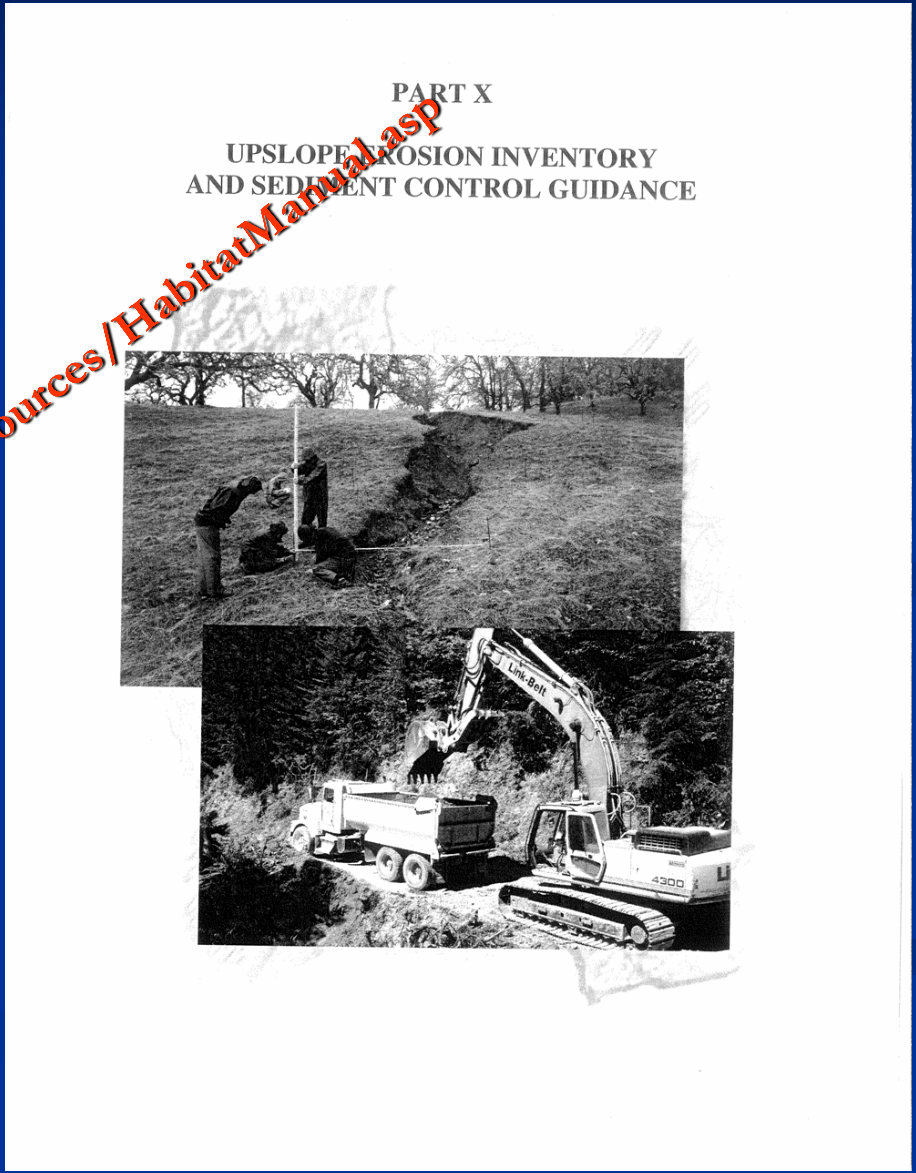
PROFESIONAL EN GEOLOGÍA
Danny Hagans
PROFESIONAL CERTIFICADO EN CONTROL DE EROSIÓN Y SEDIMENTOS
PACIFIC WATERSHED ASSOCIATES

Useful References (cont)



Upslope Inventory and Sediment Control Guidance





http://www.dfg.ca.gov/fish/Resources/HabitatManual.asp

State of California
California Natural Resources Agency
Department of Forestry and Fire Protection

Designing Watercourse Crossings for Passage of 100-Year Flood Flows, Wood, and Sediment (Updated 2017)

California Forestry Report No. 1 (revised)

Peter Cafferata, Donald Lindsay, Thomas Spittler, Michael Wopat, Greg Bundros, Sam Flanagan, Drew Coe, and William Short

August 2017